

Date of Deposit: October 30, 2000

I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to the Assistant Commissioner For Patents, Washington, D.C. 20231

By: Keith Johnson

JC951 U.S. PTO  
10/30/00

Assistant Commissioner  
for Patents  
Washington, D.C. 20231

Transmitted herewith for filing in the patent application of:

Ying-wei Lin and Jeng-nan Shiau

Entitled: COLOR TO BLACK AND WHITE CONVERTER

Enclosed are:

- ☒ 18 sheets of specification, 4 sheets of claims, 1 sheet of Abstract.
- ☒ 12 sheets of drawings, Figures 1-12.
- ☒ an assignment of an invention to XEROX CORPORATION (and transmittal therefor).
- ☒ a Declaration and Power of Attorney for Patent Application.
- ☒ Information Disclosure Statement and PTO-1449
- ☐ Preliminary Amendment

CLAIMS AS FILED

FOR	NO. FILED	NO. EXTRA	RATE	FEE
TOTAL CLAIMS	20 - 20 =	0	[XX] \$18 LARGE [ ] \$09 SMALL	\$
INDEPENDENT CLAIMS	3 - 3 =	0	[XX] \$80 LARGE [ ] \$40 SMALL	\$
BASIC FEE	[XX] LARGE ENTITY \$710 [ ] SMALL ENTITY \$355		TOTAL FILING FEE \$ 710.00	

☒ Please charge Deposit Account No. 24-0037 in the amount of \$ 710.00.

☒ The Commissioner is hereby authorized to charge any additional fees which may be required at any time during the prosecution of this application without specific authorization, or credit any overpayment to Deposit Account No. 24-0037.

☐ A check in the amount of \$ \_\_\_\_\_ to cover the filing fee is enclosed.

Date

Attorney of Record  
Joseph D. Dreher  
Reg. No. 37,123  
FAY, SHARPE, FAGAN,  
MINNICH & MCKEE, LLP  
1100 Superior Avenue  
Seventh Floor  
Cleveland, Ohio 44114-2518  
(216) 861-5582

## COLOR TO BLACK AND WHITE CONVERTER

### 5 BACKGROUND OF THE INVENTION

#### 1. FIELD OF THE INVENTION

The invention relates to the art of image rendering. It finds application where color images are rendered with a single colorant. For example, the invention finds application in repro-graphic machines where a color image is scanned and then transformed for rendering so that single colorant (black and white) copies of the color image can be made. The invention finds further application in general-purpose computing devices such as personal computers and business graphics authoring devices. In the latter devices, color images such as bar and pie charts are created in color and displayed on a computer display and then are printed on black and white printers through the use of the invention. All these devices and devices like them are referred to herein as image processors.

#### 2. DESCRIPTION OF RELATED ART

Communicating concepts and ideas to others can be difficult. One method often used to communicate ideas to a group of people is to make a visual presentation. In a visual presentation, images such as charts, graphs and photographs are often displayed before the audience while the speaker explains and describes the significance of the images. Alternatively, the images can act as summaries of an associated speech. Typically, the images are presented in color. Color often adds to the impact and clarity of an image. For example, a pie chart or a bar graph is easier to read if its various sections are presented in different colors.

Copies of visual presentation material are often distributed to the audience members. The distributed materials serve to document the presentation. The distribute material can help audience members follow the presentation and can serve as study aids and/or reference material.

Unfortunately, it can be impractical or prohibitively expensive to distribute a large number of color copies of presentation material. Furthermore, in some cases,

color reproduction equipment is not readily available. In these cases, the color images are often reproduced in black and white.

Creating black and white versions of color images can be problematic. Typically, a great deal of information is lost in the conversion to black and white. For example, typical, color image authoring devices can produce over sixteen million different colors, while typical black and white rendering devices can only produce two hundred fifty six shades of gray. Obviously, a great number of colors must be mapped to each level of gray. Therefore, portions of a color image that are quite obviously different colors can appear to be the same color when the image is rendered in black and white. When the image portions in question are, for example, different sections of a pie chart, this loss of information can render the pie chart useless.

Attempts have been made to alleviate this problem by using texturing to increase the number of ways colors can be represented in a black and white image. Typically, under these strategies, the conversion to black and white is accomplished by dividing colors into a finite number of bins and assigning a different halftone pattern to each of the bins. This approach can preserve more information from the color image. However, this approach can also lead to abrupt transitions in the black and white image. Where colors in the original image smoothly blend from one color to another, the blend in color can cross a bin boundary, resulting in a sudden shift in a halftone pattern or level. This problem is particularly pronounced when colors are near neutral or gray. This situation can be further aggravated by the presence of noise in the image. For example, a subtle jitter or shift in the color in a photograph of a person's face can be transformed into dramatic changes in halftone patterns if the jitter or shift is across one or more bin boundary.

Therefore, a method for rendering a color image in black and white is desired that preserves more of the information present in a color image. Furthermore a method is desired that accurately portrays smooth or subtle transitions in color as equally smooth or subtle transitions in texture.

## BRIEF SUMMARY OF THE INVENTION

To those ends, a method for generating a single colorant version of a multicolor image, that preserves color information in the image, has been developed.

The method comprises the steps of generating a continuously variable screening tool operative to provide a unique texture corresponding to each hue and saturation in the color image, and transforming the multicolor description of the image through the continuously variable screening tool thereby creating a single-colorant description of the image.

In some embodiments, the step of generating a continuously variable screening tool further comprises defining a neutral screen associated with neutral color, defining a plurality of primary screens associated with a plurality of hues from the multicolor color space and generating a set of blended screens associated with a set of remaining hues by performing a weighted blend between nearby screens.

An image processor operative to use the method to render a single colorant version of a multicolor image comprises a continuously variable screening tool generator operative to generate a different screen texture for every hue and saturation in the multicolor image.

In some embodiments of the image processor, the continuously variable screening tool generator further comprises a reference screen storage device operative to store a set of predetermined reference screen patterns in association with locations within a color space and a screen blender operative to access the screen storage device and use the reference screens to calculate screen patterns for colors in the multicolor image that do not correspond to locations in the color space associated with the reference screens.

One advantage of the present invention resides in the ability to generate black and white versions of color images that preserve information coded in even subtle color differences.

Another advantage of the present invention is found in the ability to render different colors having the same luminance so that they can be distinguished in a black and white version of the image.

Yet another advantage of the present invention stems from the fact that it requires very little extra system resources such as, for example system memory.

A further advantage of the present invention is that it requires only a minimal amount of extra calculation and therefore can be carried out very quickly.

Still other advantages of the present invention will become apparent to those

skilled in the art upon a reading and understanding of the detail description below.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments, they are not to scale, and are not to be construed as limiting the invention.

FIGURE 1 is a black and white version of a color map rendered through the use of a prior art method by a prior art image processor;

FIGURE 2 is a black and white version of a color pie chart rendered through the use of a prior art method by a prior art image processor;

FIGURE 3 is a flow chart outlining a method to preserve color information in a single colorant version of a multicolor image;

FIGURE 4 is a chart showing reference screens, used in some embodiments, to carry out a step in the method of FIGURE 3, the reference cells being distributed about a color space to show an assigned relationship between the reference screens and the color space;

FIGURE 5 shows numerical representations of some of the reference screens of FIGURE 4;

FIGURE 6 shows numerical representations of an intermediate and a final version of a calculated blended screen based in part on the reference screens of FIGURE 5;

FIGURE 7 is a diagram showing, in graphical form, the calculation of the blended screen of FIGURE 6. FIGURE 8 is a chart showing the reference screens of FIGURE 4 in relation to the color space of FIGURE 4 and to a set of calculated blended screens; FIGURE 9 is a block diagram illustrating processing flow in an embodiment of the method of FIGURE 3;

FIGURE 10 is a black and white version of a color map rendered by the method outlined in FIGURE 3;

FIGURE 11 is a black and white version of a color pie chart rendered by the method outlined in FIGURE 3; and

FIGURE 12 is a block diagram of an image processor operative to carry out

the method of FIGURE 3.

#### DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings wherein the showings are for purposes of illustrating the invention and not for purpose of limiting the same thereto, FIGURE 1 illustrates a black and white or single colorant version of a color map of Africa **110** produced by a prior art image processor by transforming colors to shades of gray. The transformation is accomplished, for example, by measuring or calculating a lightness level for each color in the image and then producing a shade of gray corresponding to each lightness level. This technique has drawbacks. For example, in the original color image (not shown), The Western Sahara and Morocco are clearly separate countries. The Western Sahara is rendered in yellow and Morocco is depicted in a light shade of cyan. However, in the prior art black and white version of the image of Africa **110**, The Western Sahara **114** is almost indistinguishable from Morocco **118**. Furthermore, in the prior art image of Africa **110**, Equatorial Guinea **122** is indistinguishable from its neighbor Gabon **126** even though Equatorial Guinea is rendered in cyan and Gabon is shown in light brown in the original color image. Additionally, the originally green area designating Somalia **130** and the originally pink area designating Kenya **134** appear to be one medium gray country in the prior art map of Africa **110**. Similarly, the prior art image processor has united the dark yellow area for Zambia **142** and the taupe area designating Zimbabwe **146**.

Referring to FIGURE 2, in a prior art black and white or single colorant rendition **210** of a color pie chart (not shown), first pie wedges **214**, originally rendered in red, and second pie wedges **218**, originally rendered in green, are rendered in the same shade of gray. Furthermore, originally yellow pie wedges **222** are rendered as white and have, therefore, entirely disappeared from the chart **210**.

Referring to FIGURE 3, a method **310** of generating a single colorant version of a color image, which does not suffer from the problems described in relation to FIGURE 1 and FIGURE 2, includes a continuously variable screening tool generation step **314**. As will be explained in detail below, a continuously variable screening tool is a tool for applying a unique modulation or texture to an image based on variation in some aspect of the image. For example, a continuously variable screening tool







period = Screencell Size; \*/for example, 16/\*

periodDiv2 = period/2;

amp = 127.5;

c1 = 2.0 \* 3.1416 / period;

5 the index i and j goes from 0 to period-1;

round(...) denotes rounding the argument to an integer; and

rem(a,b) is the remainder of dividing a by b.

S0:neutral(i,j) = round(127.5 - amp \*cos(c1\*i) \* cos(c1\*j));

10

S1:red(i,j) = round(127.5 - amp\*cos(c1\*(j+i)));

S3:green(i, j) = round(127.5 - amp\*cos(c1\*(j-i)));

15 S6:magenta(i,j)= round(127.5 - amp\*cos(c1\*(j+i+4\*sin(c1\*j))));

S4:cyan(i,j) = round(127.5 - amp\*cos(c1\*(i-j-4\*sin(c1\*j))));

S5:blue(i,j) determined as follow:

20

red = round(127.5 - amp\*cos(c1\*(j+i)));

green = round(127.5 - amp\*cos(c1\*(j-i)));

i1 = rem(i, period) - periodDiv2;

j1 = rem(j, period) - periodDiv2;

if(i1\*j1 >=0)

25

blue(i,i) = red;

else

blue(i,j) = green;

S2: yellow(i,j) determined as follow:

red = round(127.5 - amp\*cos(c1\*(j+i)));

30

green = round(127.5 - amp\*cos(c1\*(j-i)));j

i1 = rem(i, period) - periodDiv2;

j1 = rem(j, period) - periodDiv2;

```

        if(i1*j1 >=0)
            yellow(i,j) = green;
        else
            yellow(i,j) = red;

```

5

Referring to FIGURE 5, numerical representations of the neutral screen  $S_0$  and two primary screens  $S_1$  and  $S_2$  include threshold values **505** and relative dot position information **510**. The screens each contain threshold values **505** for two hundred fifty six dots. The dots correspond to pixels in an image. Furthermore, the dots correspond to dot or mark positions in a rendering of the image. In the screens, the dots are grouped in, for example 16 x 16 arrays or grids. Other screen sizes are acceptable and contemplated. FIGURE 5 includes column indexes **514** ranging from 1 to 16 and each screen is associated with a set of row indexes **518** ranging from 1 to 16. The relative dot position information is coded in the row **518** and column **514** indexes. In each screen  $S_0$ ,  $S_1$ ,  $S_2$ , dot locations (1,9) and (9,1) hold maximum threshold values, namely 255. Furthermore, at dot location (9,9) each screen holds minimum threshold values, namely 0. Whatever screens are used, it is preferable that each screen in the set has at least one maximum in a dot location where the other screens also have a maximum. Likewise, it is preferable that each screen in a set has at least one minimum threshold value at a dot location where the other screens in the set also have minimums. Maintaining this relationship between screens helps ensure smooth transitions in patterns as colors across an image make subtle variations. For example, maintaining this relationship ensures that subtle variations in flesh tones are depicted as subtle variations in halftone texture.

The patterns in FIGURE 4 are created by comparing a reference value, for example 128, to the threshold values in the screens. For example, comparing a reference value to the thresholds in  $S_0$  of FIGURE 5 and placing a mark at a corresponding dot location on a piece of paper wherever the reference value is above the threshold creates the pattern of  $S_0$  of FIGURE 4. The center portion of each screen  $S_0...S_6$  is dark because the threshold value in the center of each screen is zero. Therefore, any reference value greater than zero is above the threshold in the center of the screen and a mark is placed in the dot location corresponding to the center of the

screen. Close inspection of FIGURE 5 reveals that the higher the reference value is, the more marks will be placed and the darker and thicker the pattern will be. This would be appropriate where the pixel value being compared to the screens is pixel darkness. However, typically the value being compared to a screen threshold value is a pixel lightness or luminance, with increasing numerical values corresponding to brighter colors. Therefore, the sense of the marking operation is typically reversed with respect to the operation just described. In other words, typically marks are placed on print media when an image pixel value is below a screen threshold value. The result is that the patterns shown are inverted with respect to light and dark.

Examination of FIGURE 4 and FIGURE 5 also show that there are screens defined for only seven points in color space. While variations in lightness are accounted for automatically by the threshold patterns in the screens, there are still a multitude of colors for which screens are not defined. Those colors are accounted for, and the screen is made continuously variable by, calculating required screens, for example, by an image processor at run time, by blending or interpolating between the reference screens  $S_0...S_6$ . This process generates unique screens for hues and saturations not covered by the reference screens.

Any appropriate blending technique may be used. One technique is a two-step blending. First an intermediate or hue screen is calculated based on the equation:

$$\text{Screen\_hue}(\Phi) = (1-\alpha) * S_k + \alpha * S_{k+1} \quad (1)$$

Where  $k$  and  $k+1$  are primary screen numbers of screens near a color or hue of interest. The screen numbers  $k$  and  $k+1$  are selected so that  $\Phi_k < \Phi < \Phi_{k+1}$ , where  $\Phi$  is the hue angle of the color of interest,  $\alpha$  is a weighting factor. Linear or nonlinear weighting factors may be used. For example,  $\alpha$  is calculated from the equation:

$$\alpha = (\Phi - \Phi_k) / (\Phi_{k+1} - \Phi_k) \quad (2)$$

Referring to FIGURE 4, a color  $P$  has a hue angle  $\Phi$  located between the hue angles of  $S_1$  and  $S_2$ . Therefore,  $\Phi_k < \Phi < \Phi_{k+1}$  is satisfied by  $k = 1$ . For example,  $\Phi = 50$  degrees.  $\Phi_k = 30$  degrees and  $\Phi_{k+1} = 90$  degrees. Therefore

$$\alpha = (50 - 30) / (90 - 30) = 20/60 = 1/3 \quad (3)$$

and:

$$\begin{aligned} \text{Screen\_hue}(\Phi) &= (1-(1/3))*S_1 + (1/3)*S_2 \\ &= (2/3)*S_1 + (1/3)*S_2 \end{aligned} \quad (4)$$

The color **P** is located in color space one third of the way between locations associated with  $S_1$  and  $S_2$ . Therefore, the intermediate hue screen calculation is automatically weighted, by the structure of general equations (1) and (2), and as illustrated by example equations (3) and (4), so that the influence of  $S_1$  is greater than the influence of  $S_2$ .

Next, the intermediate screen ( $\text{Screen\_hue}(\Phi)$ ) is blended with the neutral screen. Again, a weighting factor is used. For example, a weighting factor based on some function of saturation  $\sigma$  is used. Again, the weighting factor function can be linear or non-linear. This second blending step makes texture variation based on color saturation a component of the continuously variable screening tool. The neutral screen / intermediate screen blending is achieved by, for example, the equation:

$$\text{Screen}(\Phi, \sigma) = (1-w(\sigma))*S_0 + w(\sigma)*\text{Screen\_hue}(\Phi) \quad (5)$$

Referring to FIGURE 6, an intermediate screen **610** includes a minimum at location (9,9) and a maximum at locations (1,9) and (9,1). The intermediate screen **610** is calculated based on equation (4). For example, with reference to FIGURE 5, in primary screen  $S_1$  the threshold value at grid location (3,2) is 79. In primary screen  $S_2$  the threshold value at grid or dot location (3,2) is 10. Applying equation (4) leads to:  $(2/3)(79) + (1/3)(10) = 56$ . Therefore, the threshold value in the intermediate screen **610** at location (3,2) is 56. The same process is repeated, as required, for each grid or dot location in the intermediate screen **610**. Likewise, a final blend screen **620** is calculated based on equation (5) under the assumption that  $w(\sigma) = 2/3$ . For example, with reference to FIGURE 5, in neutral screen  $S_0$ , the threshold value at grid location

(3,2) is 44. In the intermediate screen **610** the threshold value at grid or dot location (3,2) is 56. Applying equation (5) leads to:  $(1/3)(44) + (2/3)(56) = 52$ . Therefore, the threshold value in the final blend screen **620** at location (3,2) is 52. Again, the same process is repeated, as required, to calculate the threshold value for each grid or dot location in the final blend screen **620**. It is noted that final blend screen **620** also includes a minimum at location (9,9) and a maximum at locations (1,9) and (9,1).

FIGURE 7 illustrates the blending operation of equations (4) and (5) and FIGURE 6 in graphical form. Primary screen  $S_1$  **710** is multiplied by  $2/3$  and added to  $1/3$  of primary screen  $S_2$  **714**. The result of that calculation is an intermediate screen **718**. Next, the neutral screen  $S_0$  **722** is multiplied by  $1/3$  and added to  $2/3$  of the intermediate screen **718** resulting in a blend screen **726**. Dark portions **730** of the cells **710**, **714**, **718**, **722** represent low threshold values. Light portions **734** of the cells **710**, **714**, **718**, **722** represent high threshold values. Gray portions **738** of the cells **710**, **714**, **718**, **722** represent intermediate threshold values. The blending operation is quite clearly seen by examining primary screen  $S_1$  **710**, primary screen  $S_2$  **714** and intermediate screen **718**. In this example, a relatively heavy weighting factor of  $2/3$  multiplies primary screen  $S_1$  **710**. Therefore, the influence of primary screen  $S_1$  **710** is quite strong in the intermediate screen **718**. For example, the intermediate screen **718** and primary screen  $S_1$  **710** both include three dark portions **730**. The three dark portions in the intermediate screen **718**, are generally in the same location and are approximately the same shape as the three dark portions **730** in primary screen  $S_1$  **710**. However, there are some important differences in the shape of the dark portions **730** in the intermediate screen **718**. The influence of primary screen  $S_2$  **714** on the intermediate screen **718** can be seen in these shape variations. For example, at points where primary screen  $S_2$  **714** has dark portions **730** at grid or dot locations that correspond to gray portions **738** in primary screen  $S_1$  **710**, the intermediate screen has bulges or distortions in the dark portions **730**. The influence of  $S_2$  **714** is also apparent in gray regions **742** of the intermediate screen **718**. The gray regions occur where dark portions **730** of primary cell  $S_2$  **714** are blended with light portions of primary screen  $S_1$  **710**. Blending between the reference screens in a machine independent color space as described above generates a unique pattern corresponding to each unique color in the color space. As color changes from shade to shade, a new pattern is

created corresponding to each shade. A continuous rainbow or color sweep is transformed into a continuum of shifting patterns.

Referring to FIGURE 8, the original reference screens  $S_0...S_6$  are shown in relation to the rest of a continuously variable screening tool **810**. The continuously variable screening tool **810** is represented by a small sample set of calculated screens generated with the blending equations described above. A blended screen **814** is located in the  $a*b*$  plane approximately in the same location as color **P** (see FIGURE 4). Therefore the blended screen **814** is very similar to the blended screen **620, 726** of FIGURE 6 and FIGURE 7.

While the described system varies the screen as a function of hue and saturation, continuously variable screening tools can be functions of other color description parameters. The choice is limited only by the parameters that describe the color space in which one chooses to work.

Any convenient screen dimension can be used. For example, screens containing screens with dimensions of 10 dots x 10 dots, 12 dots x 12 dots and 16 dots x 16 dots are common. Cell dimensions are chosen for the usual reasons of spatial and gray level resolution.

In operation, for example, during the image transformation step **318**, a color image can be thought of as being overlaid with an array of generic screens. This effectively assigns each pixel in the color image to a particular dot position within a screen. For example, some pixels are assigned dot or grid location (3,2). Other pixels are assigned dot location (9,9) and so on and so forth for all the available dot locations (depending on the size of the screens). Each pixel is analyzed and is associated with one of the reference screens or with a screen that is calculated from an interpolation or blend of the reference screens (in, for example, step **314** for that pixel). For example, equation (1) and equation (5), described above, are used to calculate a screen for a pixel base on a hue and a saturation described by the pixel. A pixel value, for example, a pixel lightness or luminance, is then compared to the threshold value corresponding to the dot location assigned to the pixel. If the pixel value is below (or above, depending on the system) the threshold value a mark will be placed on a media. Of course, the media can be any image storage device or rendering media. For example, a mark or bit can be set in an electronic storage device, a dot can be

printed on a piece of paper, or a pixel location can be made dark (or light) on a monochrome monitor. Of course, it is not necessary to generate an entire calculated screen. It is only necessary to calculate the threshold value associated with the dot location assigned to the pixel of interest. For example, if the pixel is assigned dot location (3,2) then it is only necessary to use equations (1) and (5) to calculate a threshold value for dot location (3,2). Alternatively an entire screen may be calculated and stored for use with other similar pixels.

Indeed, any number of implementations are possible. Implementations range from memory intensive, continuous screening tool precalculation and look up table generation and storage schemes, to a calculation intensive, on the fly screen calculation techniques. Image processors can range from analog and/or digital computer implementations to fuzzy logic or neural network implementation.

Referring to FIGURE 9, preferably, when an embodiment uses on the fly screen blending, blending is done one dot location at a time. For example, a pixel address counter 914 generates an image address for an image pixel. A screen address generator 918 receives the image address and relates it to a screen dot location 510 using modular arithmetics. For example, a scanline number and a pixel position within a scanline are used to determine that the image pixel is related to, for instance, screen dot position (7,13). Where necessary, a color converter 922 is used to determine convenient pixel values from available pixel values. For example,  $a*b*$  values of the image pixel addressed by the pixel address counter 914, are converted to more convenient hue and saturation values. A set of primary screens 926 is accessed. As described in reference to equation (1), the pixel hue value is used to select two of the primary screens 926 for blending. Additionally, the screen dot location generated by the screen address generator 918 is used to select appropriate screen threshold values from the selected screens. For example, the threshold values from dot locations (7,13) from both  $S_i$  and  $S_j$  are selected for blending in a first blender 930. In FIGURE 9, those threshold values are denoted as  $v_i$  and  $v_j$ . As described in reference to equation (2), the pixel hue value is also used by the first blender 930, to calculate weighing factors for each of the selected screens. The screen dot location is use to select an appropriate screen threshold value form a neutral screen 934. For example, the screen threshold value from location (7,13) of  $S_0$  is selected for blending. In

FIGURE 9, that threshold value is denoted as  $v_0$ . An intermediately blended threshold value is delivered from the first blender **930** to a second blender **938**. As described in reference to equation (5), the pixel saturation value is used, by the second blender **938**, to calculate weighing factors for the intermediate threshold value and the neutral screen  $S_0$  threshold value. The output of the second blender is a final continuous screening tool threshold value. In FIGURE 9, the final continuous screening tool threshold value is denoted  $v$ . An image pixel luminance value  $L^*$  is compared to the final continuous screening tool threshold value in a comparator **942**. The output of the comparator **942** is a binary output. The binary output indicates whether or not a mark is to be generated as the transform of the image pixel. This procedure is repeated for every image pixel in the image. Referring to FIGURE 10, the method **310** of generating a single colorant version of a color image of FIGURE 3 is used to transform (step **318**) the color map of Africa (not shown), mentioned in reference to FIGURE 1. The color map of Africa is rendered (step **322**) as a textured black and white map of Africa **1010**. In contrast to the prior art black and white map of Africa **110**, in the textured map of Africa **1010** the Western Sahara **1014** is clearly distinguishable from Morocco **918**. Furthermore, Equatorial Guinea **1022** is clearly separate from its neighbor Gabon **1026**. Additionally, Somalia **1030** and Kenya **1034** are rendered with textures as distinct from one another as their original green and pink colors. Similarly, Zambia **1042** and Zimbabwe **1046** are properly rendered as separate countries.

Referring to FIGURE 11, in contrast to the prior art image processor, which failed to distinctly transform primary colors in the pie chart **210** shown in FIGURE 2, in a textured black and white pie chart **1110** first pie wedges **1114**, created as red and second pie wedges **1118**, created as green, are rendered with distinct patterns. Furthermore, originally yellow pie wedges **1122**, which are not visible in the prior art pie chart **210**, are clearly visible and rendered with a third pattern.

Referring now to FIGURE 12, an image processor **1210** operative to transform a multicolor image into a textured single colorant version comprises a continuously variable screening tool generator **1214**. The continuously variable screening tool generator **1214** is operative to generate a different screen texture for every hue in the multicolor image. For example, the continuously variable screening







and white xerographic printer. A xerographic printer is known by those skilled in the art to comprise, for example, a fuser, a developer, and an imaging member. Alternatively, the print engine 1234 may include any other image-rendering device, such as, for example, an ink jet printer, a cathode ray tube, a monochrome monitor, or  
5 a laser printer.

In some implementations, the functions of the continuously variable screening tool generator 1214, image transformer 1226 and marker 1230 are combined or performed by other devices. The architecture illustrated in FIGURE 12 is only exemplary and is not meant to limit the invention. For example, as described above,  
10 in some analog implementations a comparator provides the majority of the functions of an image transformer and a marker.

The invention has been described with reference to particular embodiments. Modifications and alterations will occur to others upon reading and understanding this specification. For example, the invention can be implemented using a color space  
15 other than the CIELAB color space. More or fewer reference screens can be used. Other reference screen patterns can be used. Reference screens do not have to be distributed about the outer edge of the color space. Blending or interpolation can be based on parameters other than hue angle and saturation. Many other image processor implementations are contemplated for using a continuously variable screening tool to  
20 generate single colorant versions of color images. Hardware, software, neural networks, application specific integrated circuits, programmable gate arrays and a host of other technologies can be used to implement versions of the image processor. It is intended that all such modifications and alterations are included insofar as they come within the scope of the appended claims or equivalents thereof.

## CLAIMS

What is claimed is:

1. A method for rendering an image described in a multi-colorant color space, in a single-colorant color space, the method comprising:

generating a continuously variable screening tool operative to provide a texture corresponding to each hue and saturation in the multi-colorant color space,

5 and

transforming the multi-colorant description of the image based on the continuously variable screening tool thereby creating a single-colorant description of the image.

2. The method for rendering an image of claim 1 wherein the step of generating a continuously variable screening tool further comprises:

defining a neutral screen associated with neutral color;

5 defining a plurality of primary screens associated with a plurality of hues from the multi-colorant color space.

3. The method for rendering an image of claim 2 further comprising the step of generating a set of blended screens associated with a set of remaining hues by performing a weighted blend between nearby screens.

4. The method for rendering an image of claim 3 wherein the step of generating a set of blended screens further comprises blending between two primary screens to generate an intermediate screen  $\text{screen\_hue}(\phi)$  using the equation:

$$\text{Screen\_hue}(\Phi) = (1-\alpha) * S_k + \alpha * S_{k+1}$$

5 where  $\Phi$  is a hue angle of a pixel being transformed,  $k$  is an index indicating one of the primary screens,  $k+1$  indicates another primary screen such that  $\Phi_k < \Phi < \Phi_{k+1}$ , where  $\Phi_k$  and  $\Phi_{k+1}$  are hue angles associated with the primary screens  $S_k$  and  $S_{k+1}$  respectively and where

$$\alpha = (\Phi - \Phi_k) / (\Phi_{k+1} - \Phi_k).$$

5. The method for rendering an image of claim 4 wherein the step of generating a blended screen further comprises blending between a neutral screen and the intermediate screen Screen\_hue( $\Phi$ ) to generate a blended screen screen( $\Phi, \sigma$ ) using the equation:

5 
$$\text{screen}(\Phi, \sigma) = (1 - w(\sigma))S_0 + w(\sigma) \text{Screen\_hue}(\Phi)$$

where  $S_0$  is the neutral screen, and  $w(\sigma)$  is a function of saturation  $\sigma$  having a value between 0 and 1.

6. The method for rendering an image of claim 3 wherein the step of generating a blended screen further comprises blending between a primary screen and the neutral screen.

7. The method for rendering an image of claim 1 wherein the step of generating a single-colorant version of the image further comprises marking media as directed by the single-colorant description of the image.

8. The method for rendering an image of claim 7 wherein the step of marking media further comprises comparing a luminance of a pixel from the image with an associated screen value and placing a mark on the media if the luminance value is above the screen value.

9. The method for rendering an image of claim 7 wherein the step of marking media further comprises comparing a luminance of a pixel from the image with an associated screen value and placing a mark on the media if the luminance value is below the screen value.

10. The method for rendering an image of claim 2 wherein the step of defining a neutral screen further comprises generating a screen based on the product of two cosine functions.

11. The method for rendering an image of claim 2 wherein the step of generating a neutral screen further comprises generating a high frequency dot screen.

12. The method for rendering an image of claim 2 wherein the step of generating a neutral screen further comprises generating a forty-five degree high frequency dot screen.

13. The method for rendering an image of claim 2 wherein the step of generating a plurality of primary screens further comprises generating a plurality of hue dependent screens, each of the plurality of screens having at least one common dot location for a maxima and at least one common dot location for a minima.

14. An image processor operative to render a single colorant version of a multicolor image, the image processor comprising:

a continuously variable screening tool generator operative to generate a different screen texture for every hue and saturation in the multicolor image.

15. The image processor of claim 14 wherein the image processor is a reprographic image processor.

16. The image processor of claim 14 wherein the image processor is a general-purpose computing device.

17. The image processor of claim 14 wherein the image processor is a business graphic authoring device.

18. The image processor of claim 14 wherein the continuously variable screening tool generator further comprises:

a reference screen storage device operative to store a set of predetermined reference screen patterns in association with locations within a color space; and

a screen blender operative to access the screen storage device and use the reference screens to calculate screen patterns for colors in the multicolor image that do correspond to locations in the color space that are different than the locations in the color space associated with the reference screens.

19. An image processor operative to render a single colorant version of a multicolor image, the image processor comprising:

a print engine;

5 a continuously variable screening tool generator operative to generate a different screen texture for every hue and saturation in the multicolor image;

an image transformer operative to apply the different generated screen textures in transforming the multicolor image to generate a single colorant version of the image;

10 a marker operative to use the single colorant version of the image as a basis for controlling the print engine to render the single colorant version of the image.

20. The image processor of claim 20 wherein the print engine is a xerographic printer.

## COLOR TO BLACK AND WHITE CONVERTER

### ABSTRACT

A continuously variable screening tool is used to generate a unique texture pattern for every color in a multicolor image. The continuously variable screening tool allows a single colorant version of the image to be generated with less information loss than typically suffered in the multicolor to single color transformation process. The continuously variable screening tool is generated by blending patterns from a set of reference screens. The reference screens are associated with selected reference colors in, for example, a machine independent color space. A calculated screen is generated through a weighted blend of reference screens located near the arbitrary color in the machine independent color space. Typically, the weights depend on the distance the arbitrary color is from each of the reference colors. The screens consist of arrays of threshold values. Each threshold value is associated with a dot position and an image pixel. Where a pixel value exceeds the associated threshold value, provision is made to place a mark in the associated dot position. An image processor operative to carry out the method comprises a continuously variable screening tool generator. An embodiment of the image processor includes a reference screen storage device and a screen blender.

C:\DATA\JDD\APPS\JDD\XER20329.APP.DOC



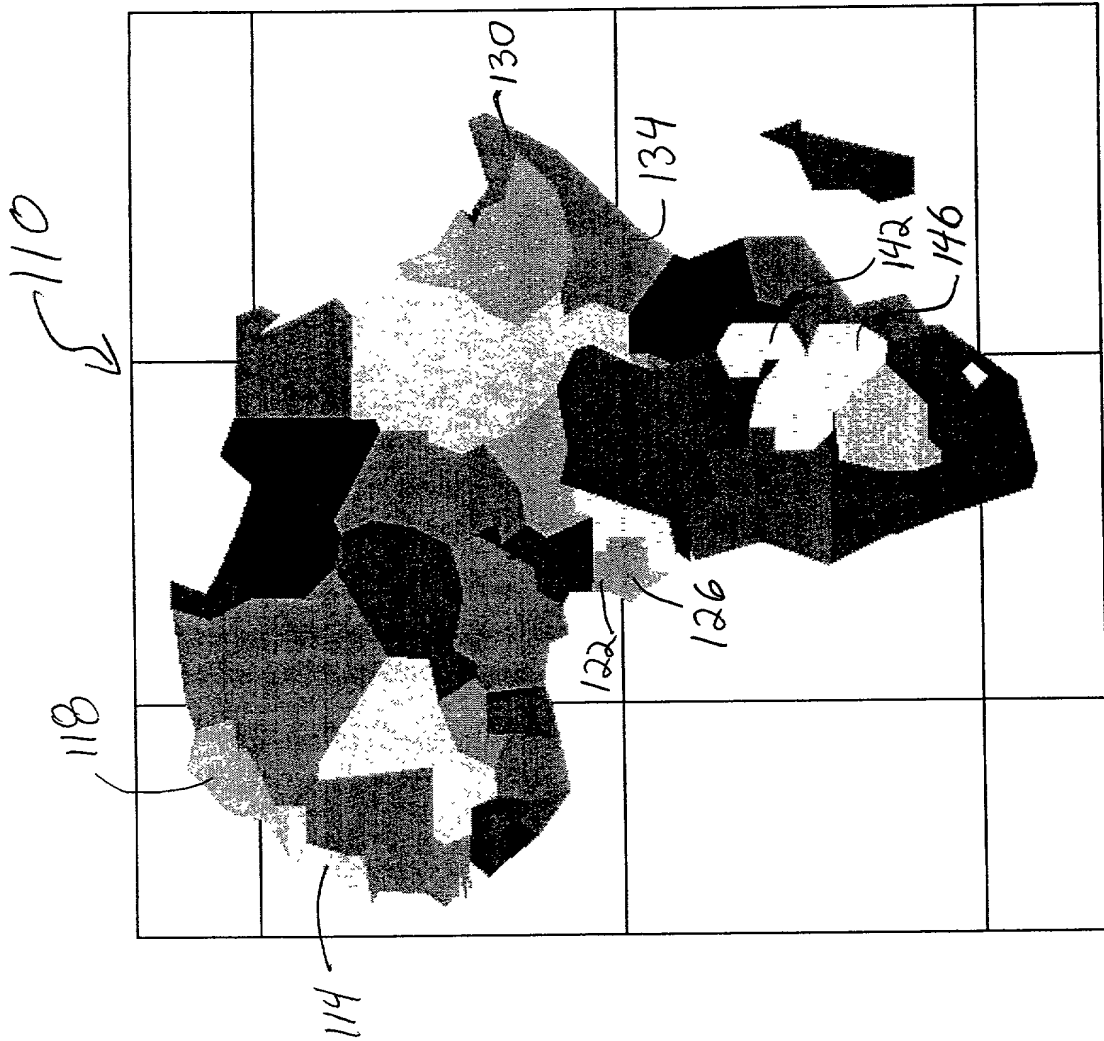


FIGURE 1 (Prior Art)

# DAIRY REVENUE COMPARED TO TOTAL SALES

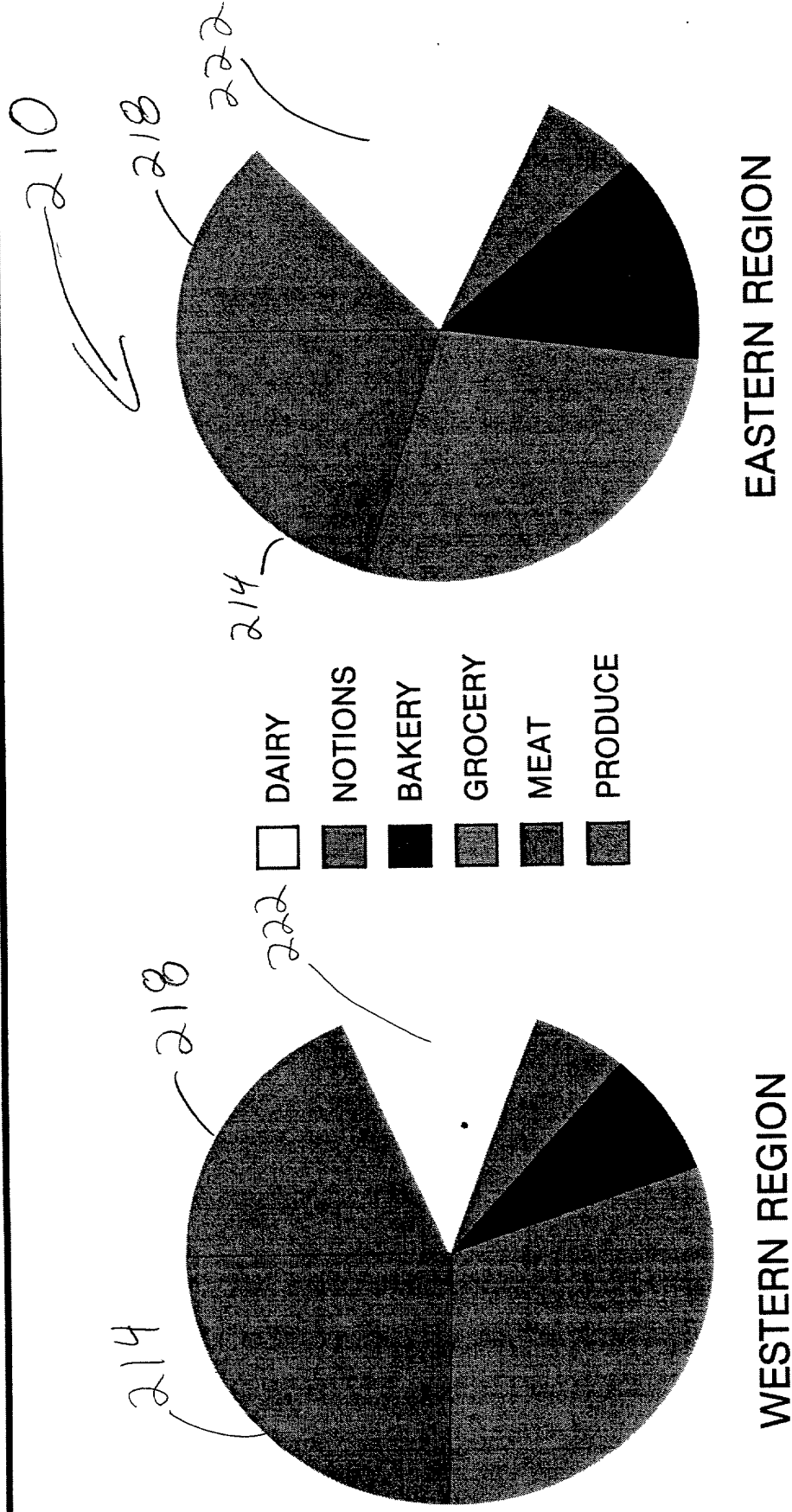


FIGURE 2 (Prior Art)

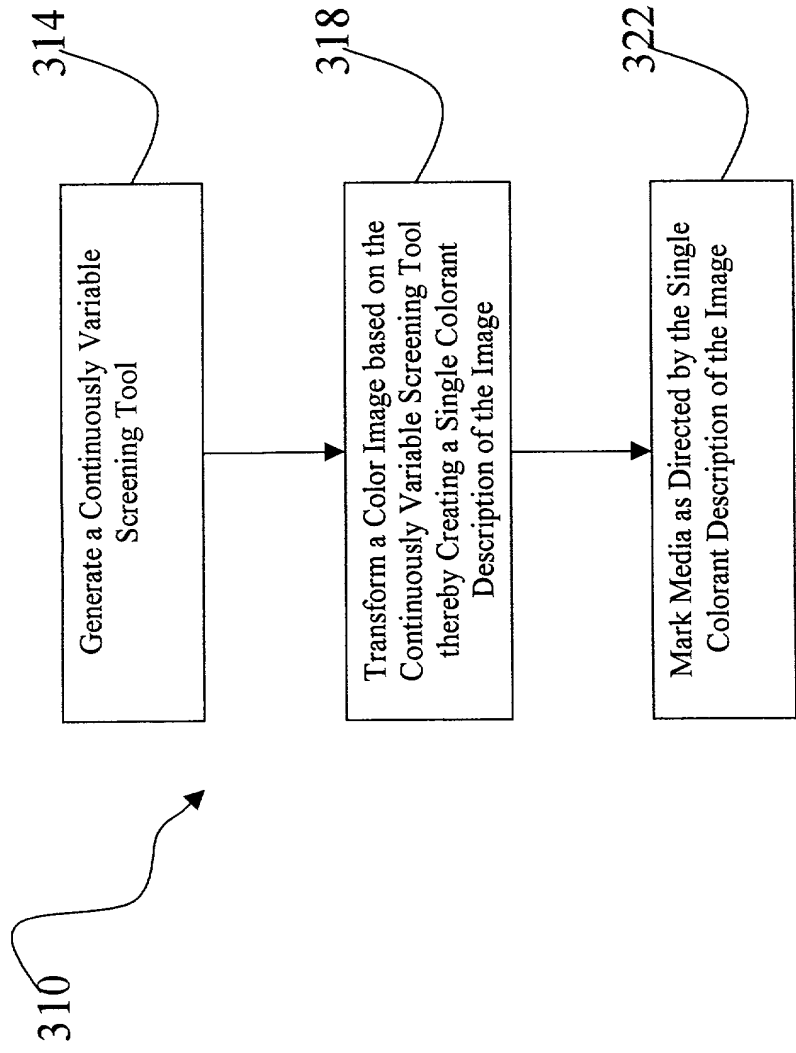


FIGURE 3

000001000000\*

$s_2$

$\phi$   
 $\phi'$

$s_1$

$s_3$

$a^*$

$s_0$

$s_4$

$s_6$

$s_5$

FIGURE 4

510

127	102	181	211
127	146	162	173
127	128	128	128
128	109	93	82
128	93	64	44
128	82	44	19

218	245	255	245	218	176
245	255	245	218	176	128
255	245	218	176	128	79
245	218	176	128	79	37

505

FIGURE 5

610

Intermediate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	10	37	79	127	176	218	245	255	245	218	176	128	79	37	10
2	10	24	56	97	143	187	222	242	245	218	176	128	79	37	10	0
3	37	56	84	120	157	189	212	222	218	176	128	79	37	10	0	10
4	79	97	120	145	166	182	189	187	176	128	79	37	10	0	10	37
5	127	143	157	166	170	166	157	143	127	79	37	10	0	10	37	79
6	176	187	189	182	166	145	120	97	79	37	10	0	10	37	79	127
7	218	222	212	189	157	120	85	56	24	10	0	10	37	79	127	176
8	245	242	222	187	143	97	56	24	10	0	10	37	79	127	176	218
9	255	245	218	176	127	79	37	10	0	10	37	79	127	176	218	245
10	245	218	176	128	79	37	10	0	10	24	56	97	143	187	222	242
11	218	176	128	79	37	10	0	10	37	56	84	120	157	189	212	222
12	176	128	79	37	10	0	10	37	79	97	120	145	166	182	189	187
13	128	79	37	10	0	10	37	79	127	143	157	166	170	166	157	143
14	79	37	10	0	10	37	79	127	176	187	189	182	145	120	85	56
15	37	10	0	10	37	79	127	176	218	222	212	189	157	120	85	56
16	10	0	10	37	79	127	176	218	245	242	222	187	143	97	56	24

620

FIGURE 6

Blend	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	10	37	79	127	176	218	245	255	245	218	176	128	79	37	10
2	10	22	52	92	137	182	218	240	245	224	187	143	95	52	21	6
3	37	52	77	111	147	180	205	218	218	187	149	106	67	37	21	21
4	79	92	111	133	153	170	180	182	176	143	106	73	49	36	37	52
5	127	137	147	153	156	153	147	138	127	95	67	49	42	49	67	95
6	176	182	180	170	153	133	111	92	79	52	37	36	49	73	106	142
7	218	218	205	180	147	111	78	52	37	21	21	37	67	106	148	187
8	245	240	182	182	138	92	52	22	10	6	21	52	95	142	187	224
9	255	245	218	176	127	79	37	10	0	10	37	79	127	176	218	245
10	245	224	187	143	95	52	21	6	10	22	52	92	137	182	218	240
11	218	187	149	106	67	37	21	21	37	52	77	111	147	180	205	218
12	176	143	106	73	49	36	37	52	79	92	111	133	153	170	180	182
13	128	95	67	49	42	49	67	95	127	137	147	153	156	153	111	92
14	79	52	37	36	49	73	106	142	176	182	180	170	153	133	111	92
15	37	21	21	37	67	106	148	187	218	218	205	180	147	111	78	52
16	10	6	21	52	95	142	187	224	245	240	218	182	138	92	52	22

000001 000000900

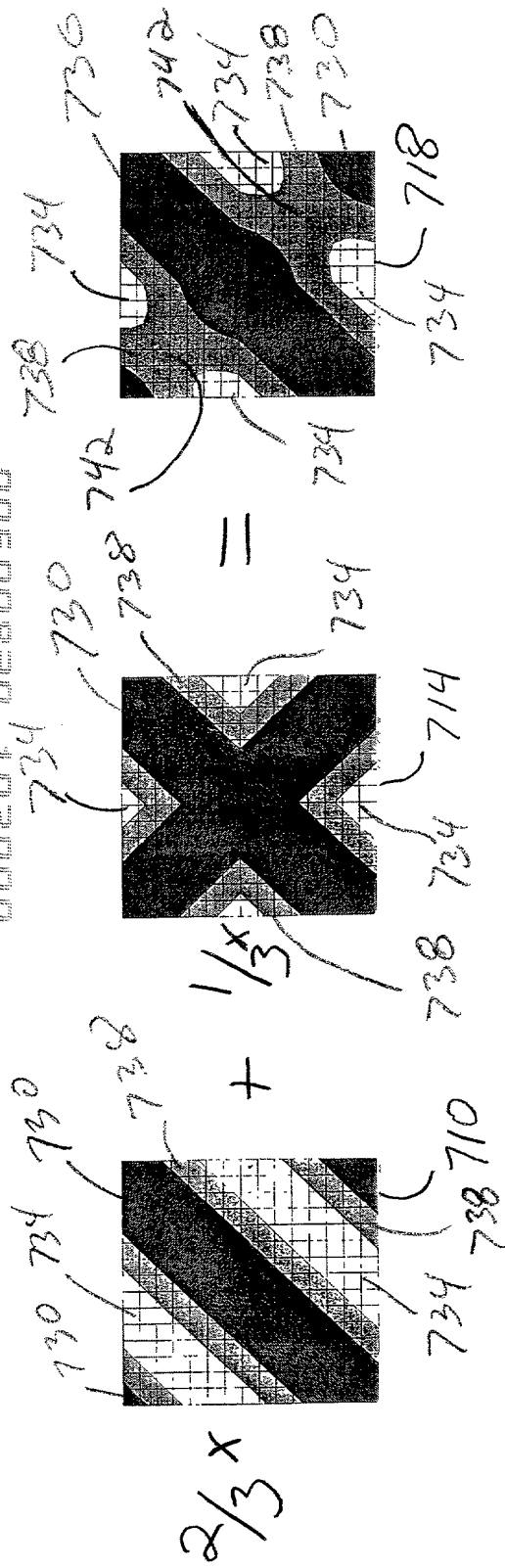
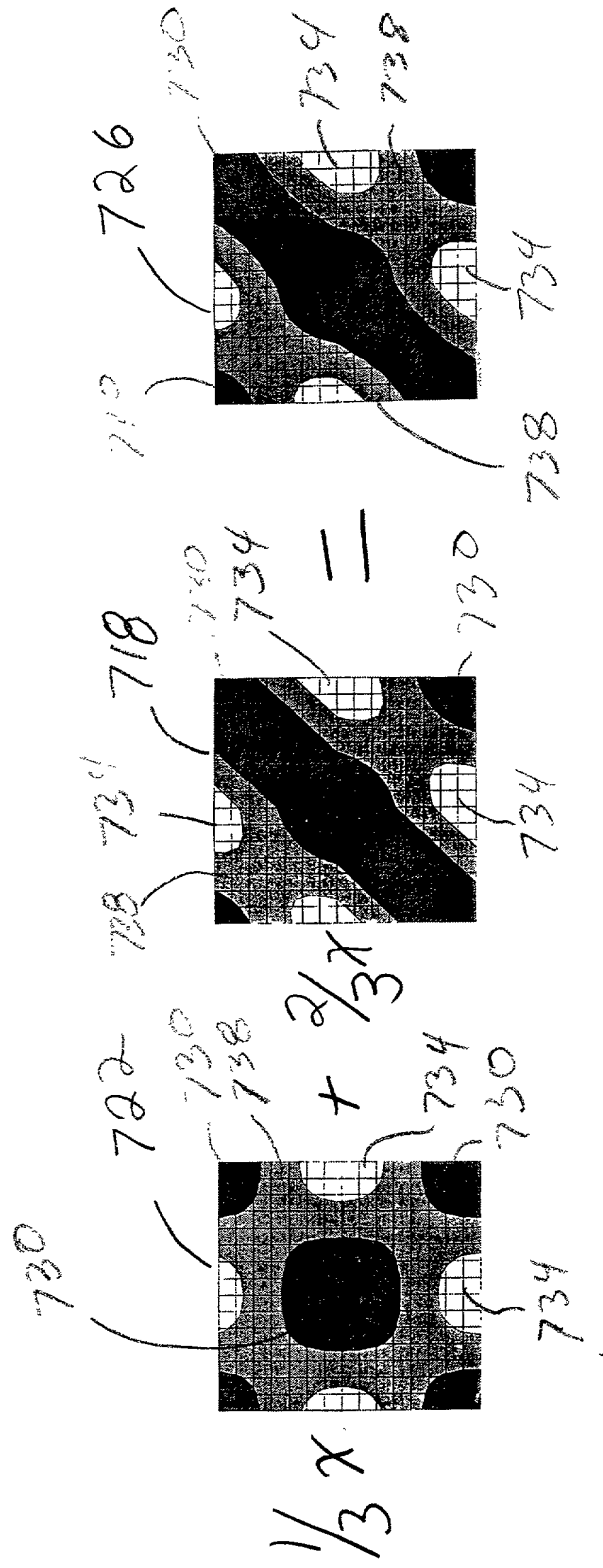


FIGURE 7



810  
↖

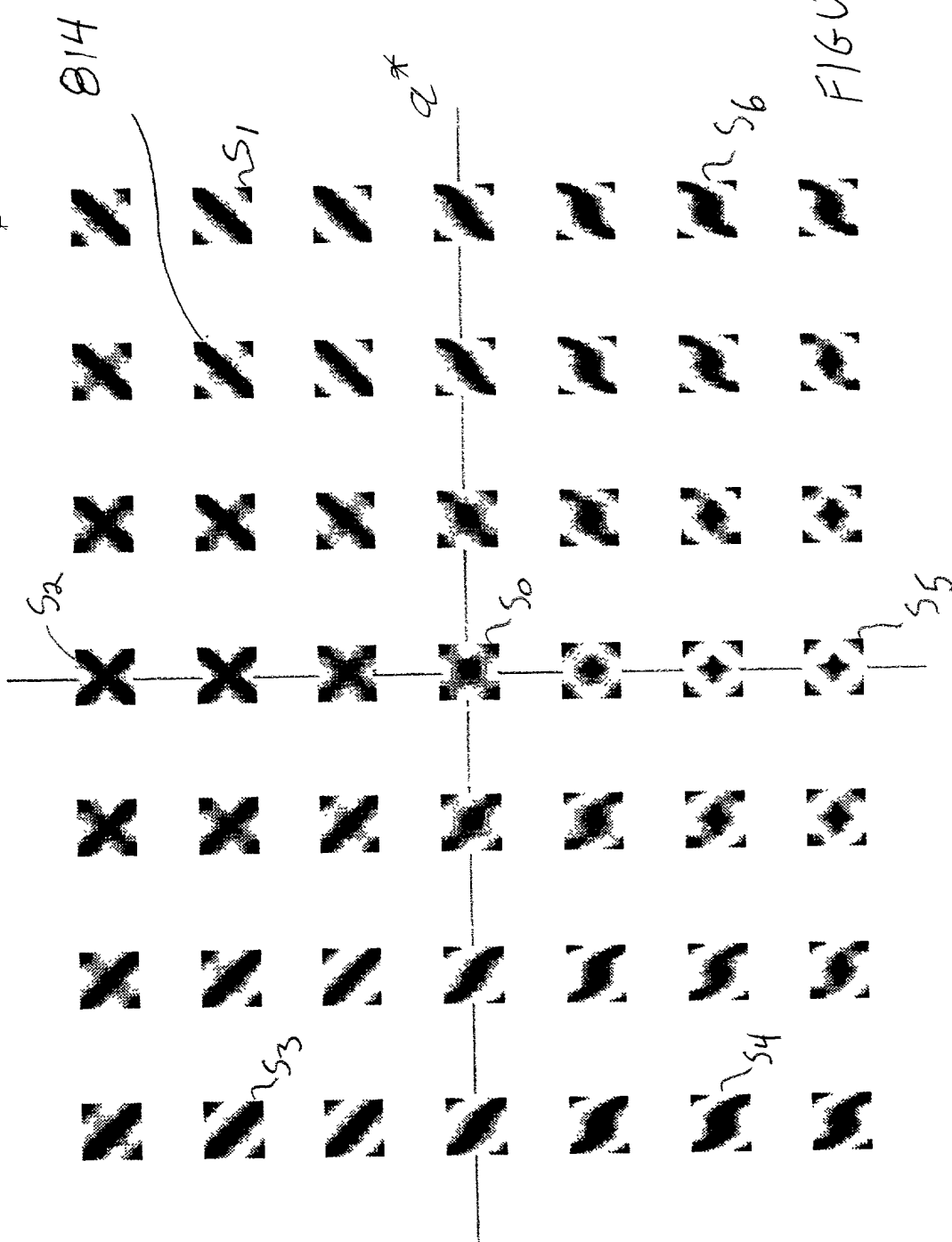


FIGURE 8



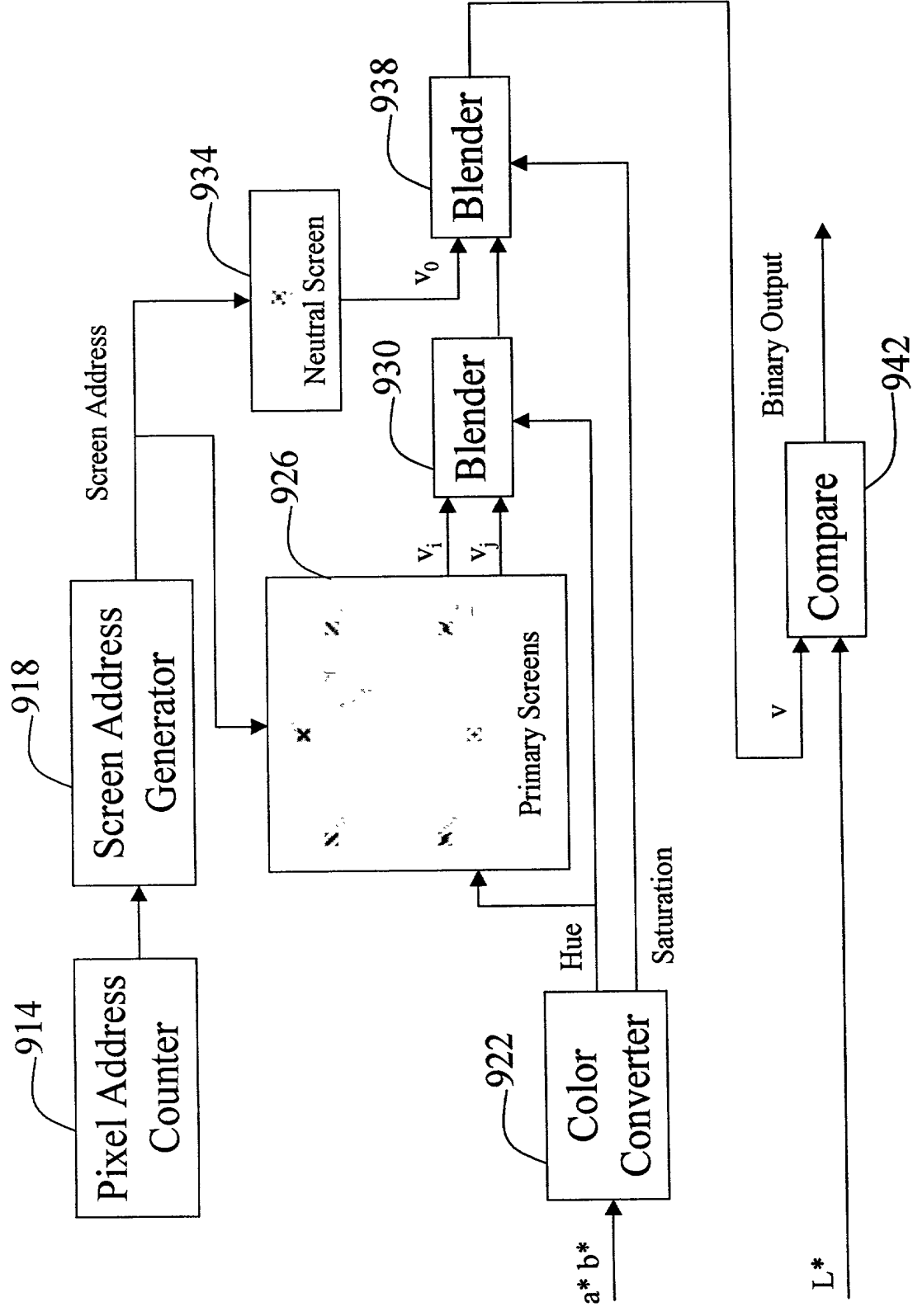


FIGURE 9

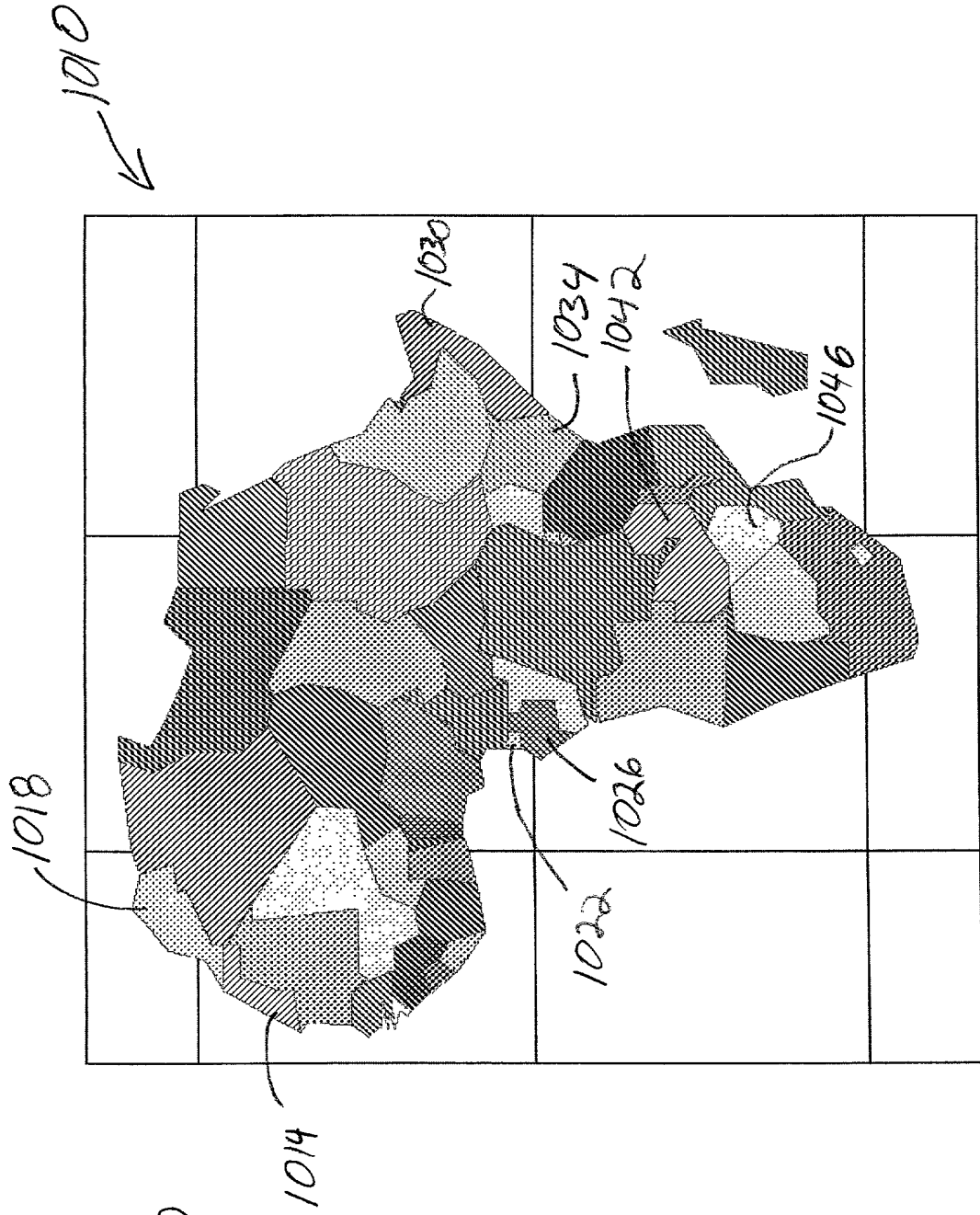
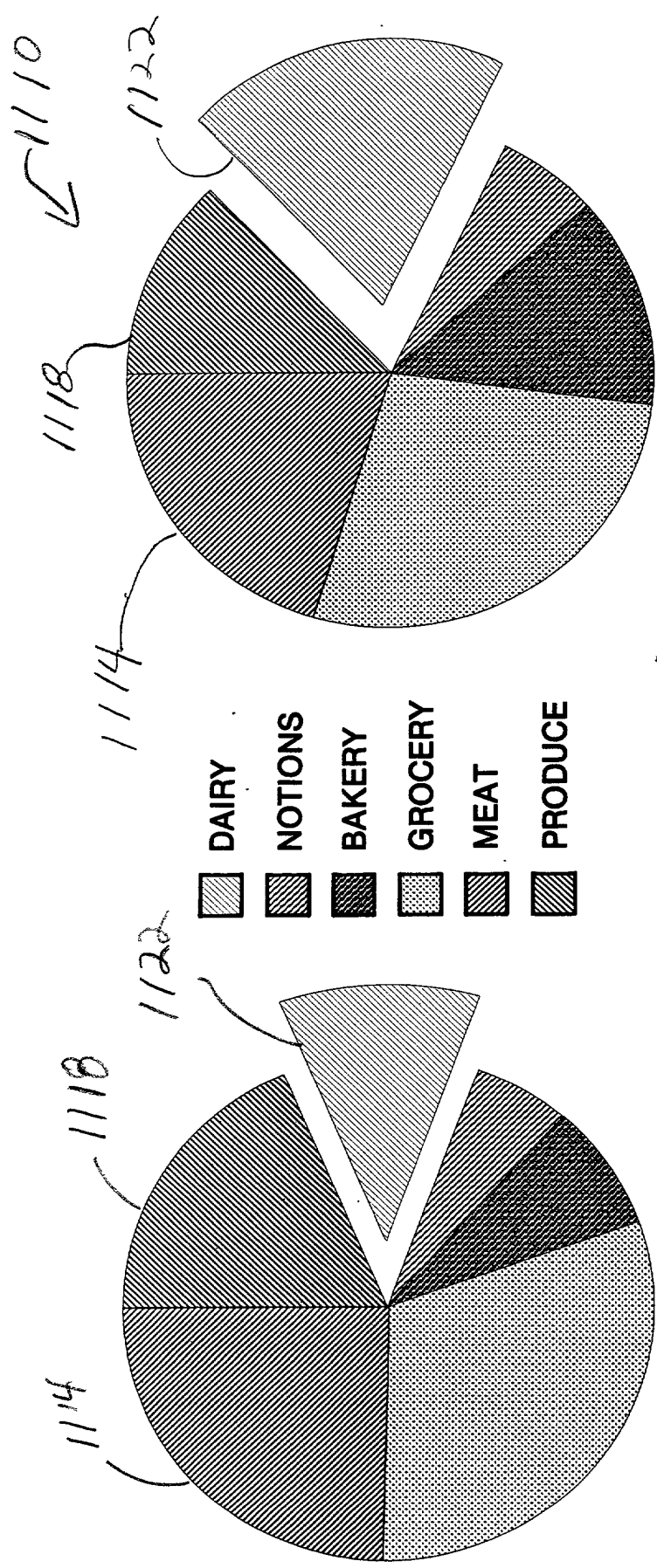


FIGURE 10

# DAIRY REVENUE COMPARED TO TOTAL SALES

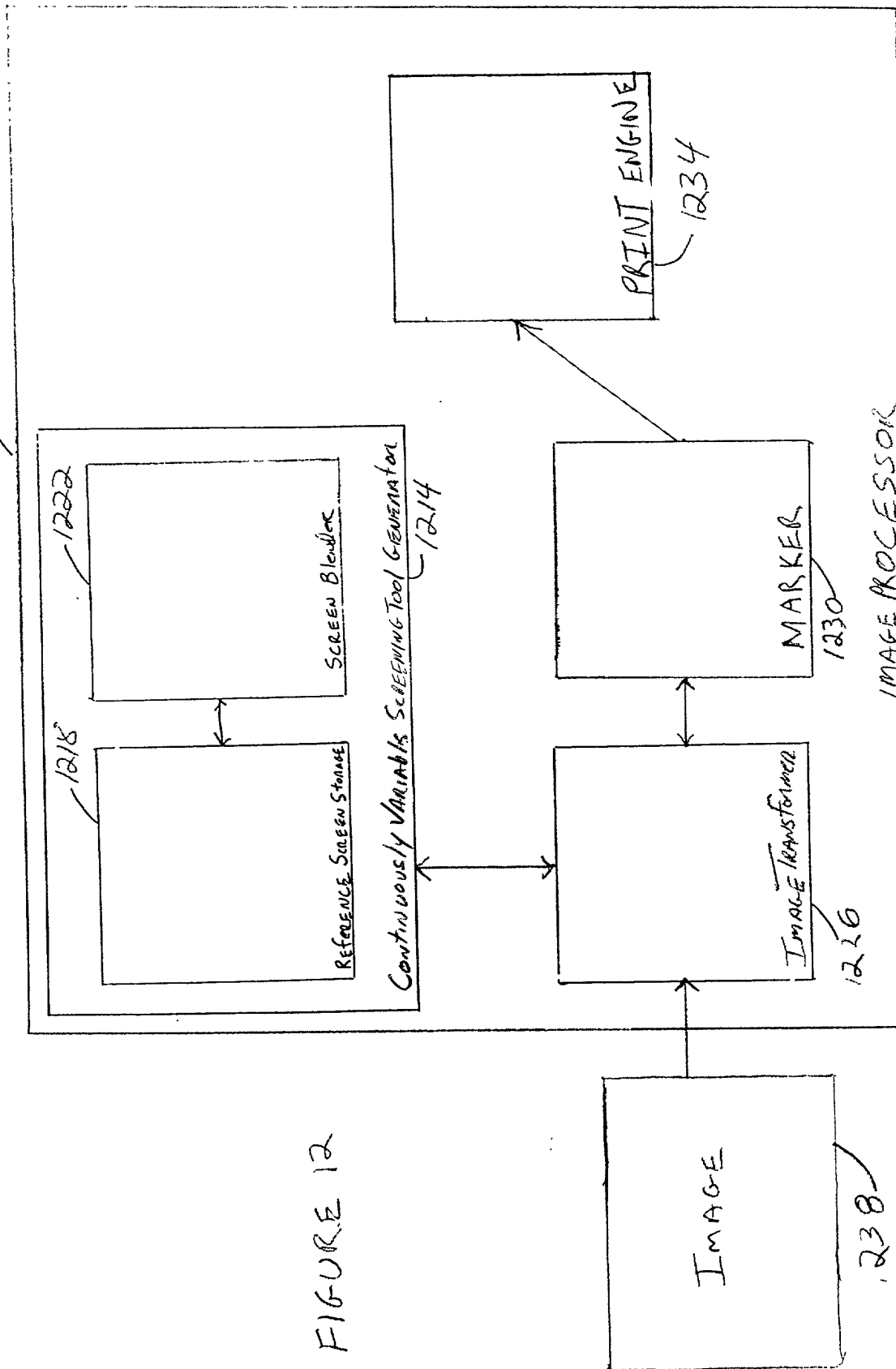


WESTERN REGION

EASTERN REGION

FIGURE 11

FIGURE 12



**DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION**

Attorney's Docket No. XER 2 0329  
D/A0125

As a below inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**COLOR TO BLACK AND WHITE CONVERTER**

the specification of which

  X   is attached hereto   OR          was filed on  
Application Serial No.  
and was amended on (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application(s) for patent or inventor's certificate or of any PCT international application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

_____	_____	_____
(Number)	(Country)	(Filing Date)

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Prior Provisional U.S. Patent Application(s):

_____	_____
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under Title 35, United States, Section 120 of any United States application(s) or any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information which is material to patentability as defined in Title 37, of Federal Regulations Code, Section 1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Prior U.S. Patent Application(s):

_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status)
		(patented, pending, abandoned)

**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Steven M. Auvil,	Reg. No. 40,492	Mark E. Bandy,	Reg. No. 35,788
Brian G. Bembenick	Reg. No. 41,463	John P. Cornely,	Reg. No. 41,687
Joseph D. Dreher,	Reg. No. 37,123	Christopher B. Fagan,	Reg. No. 22,987
Jude A. Fry,	Reg. No. 38,340	Steven M. Haas,	Reg. No. 37,841
W. Scott Harders,	Reg. No. 42,629	Michael E. Hudzinski,	Reg. No. 34,185
Richard M. Klein,	Reg. No. 33,000	Thomas E. Kocovsky, Jr.,	Reg. No. 28,383
Sandra M. Koenig,	Reg. No. 33,722	Brian E. Kondas,	Reg. No. 40,685
Scott A. McCollister,	Reg. No. 33,961	James W. McKee,	Reg. No. 26,482
Richard J. Minnich,	Reg. No. 24,175	Jay F. Moldovanyi,	Reg. No. 29,678
Philip J. Moy,	Reg. No. 31,280	Timothy E. Nauman,	Reg. No. 32,283
Patrick R. Roche,	Reg. No. 29,580	Jim Scarbrough	Reg. No. 47,056
Albert P. Sharpe, III,	Reg. No. 19,879	R. Scott Speroff,	Reg. No. 37,450
Mark S. Svat,	Reg. No. 34,261	John E. Beck	Reg. No. 22,833
Richard B. Domingo	Reg. No. 36,784	Henry Fleischer	Reg. No. 25,582
Mark Costello	Reg. No. 31,342	Eugene O. Palazzo	Reg. No. 20,881
Lloyd F. Bean, II	Reg. No. 37,775		

**SEND CORRESPONDENCE TO:**

Albert P. Sharpe, III, Esq.  
Fay, Sharpe, Fagan,  
Minnich & McKee, LLP  
1100 Superior Avenue, 7th Floor  
Cleveland, OH 44114-2518

**DIRECT TELEPHONE CALLS TO:**  
(name and telephone number)

Albert P. Sharpe, III  
(216) 861-5582

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full name of first joint inventor: **Ying-wei Lin**

Inventor's Signature: Ying-wei Lin

Residence: Penfield, New York

Country of Citizenship: U.S.A.

Date: 10/26/2000

Post Office Address:

119 Hillrise Drive  
Penfield, New York 14526

Full name of second joint inventor: **Jeng-nan Shiau**

Inventor's Signature: Jeng-nan Shiau

Residence: Webster, New York

Country of Citizenship: U.S.A.

Date: 10/26/2000

Post Office Address:

687 Shadow Wood Lane  
Webster, New York 14580